Simulation of Intermodal, Metropolitan Public Transport

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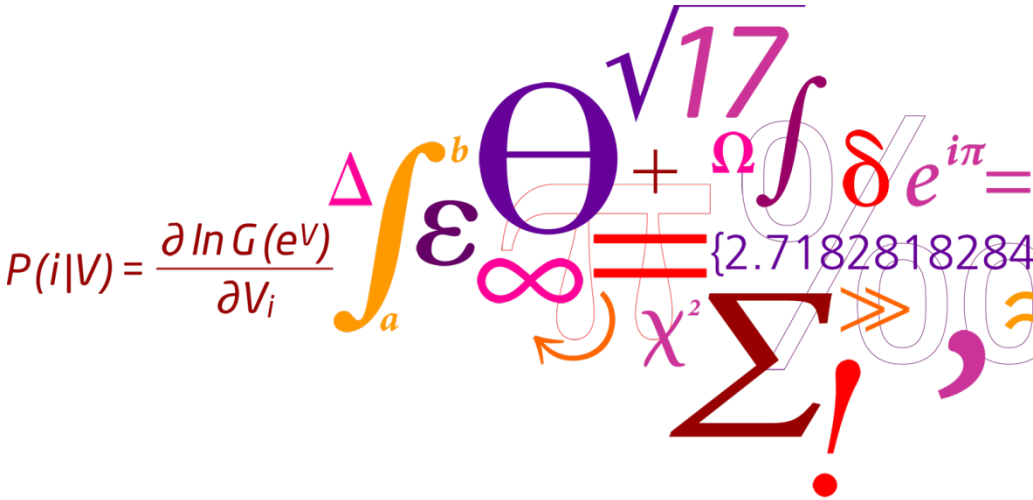


tment of Transport

A Five Year Project

- IPTOP Launch 2015
- Prior Work at DTU
- Scope of the Model
- Early Decisions

IPTOP

- ”Integrated Public Transport Optimisation and Planning”
- 8+ Million DKK (770.000 £)
- Six PhD/Postdoc

Danish Congestion

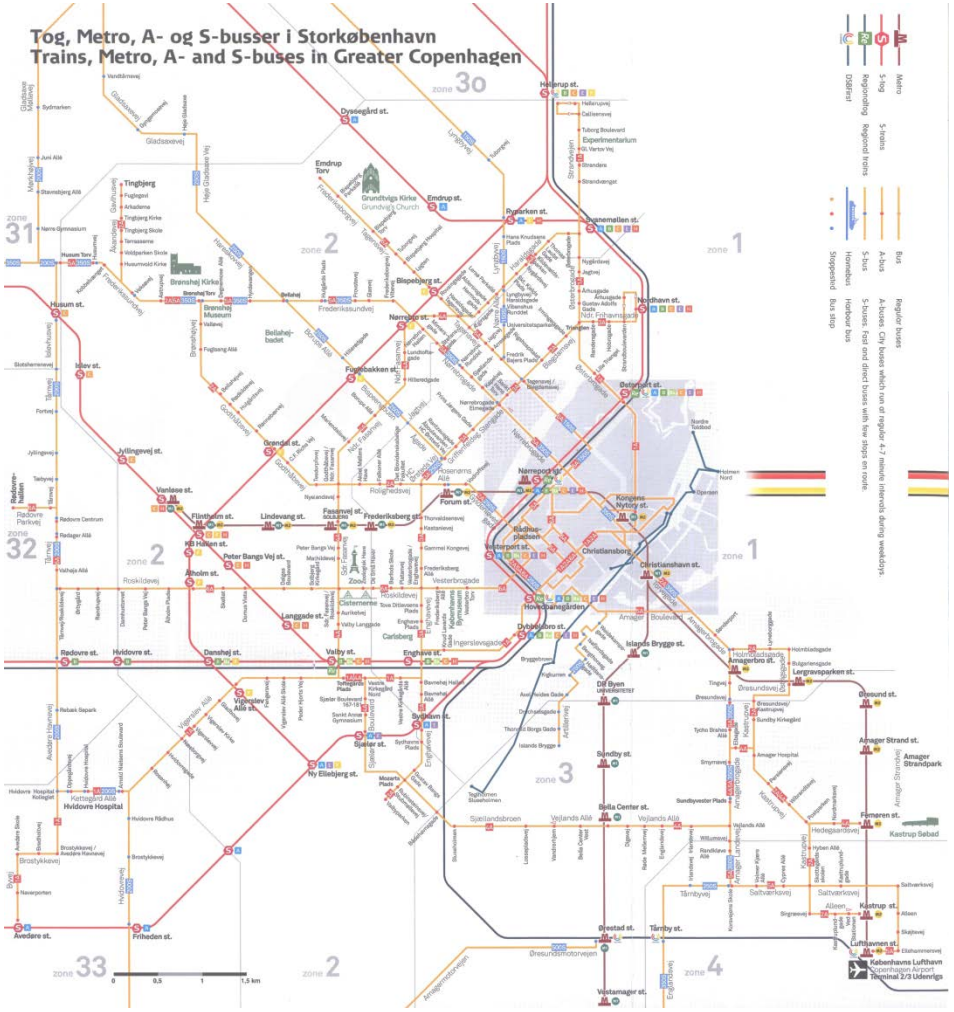
- 180% marginal car tax
- 2/3 of all kilometers by car
- More two car families
- Cycle congestion too

IPTOP – More Transit Use

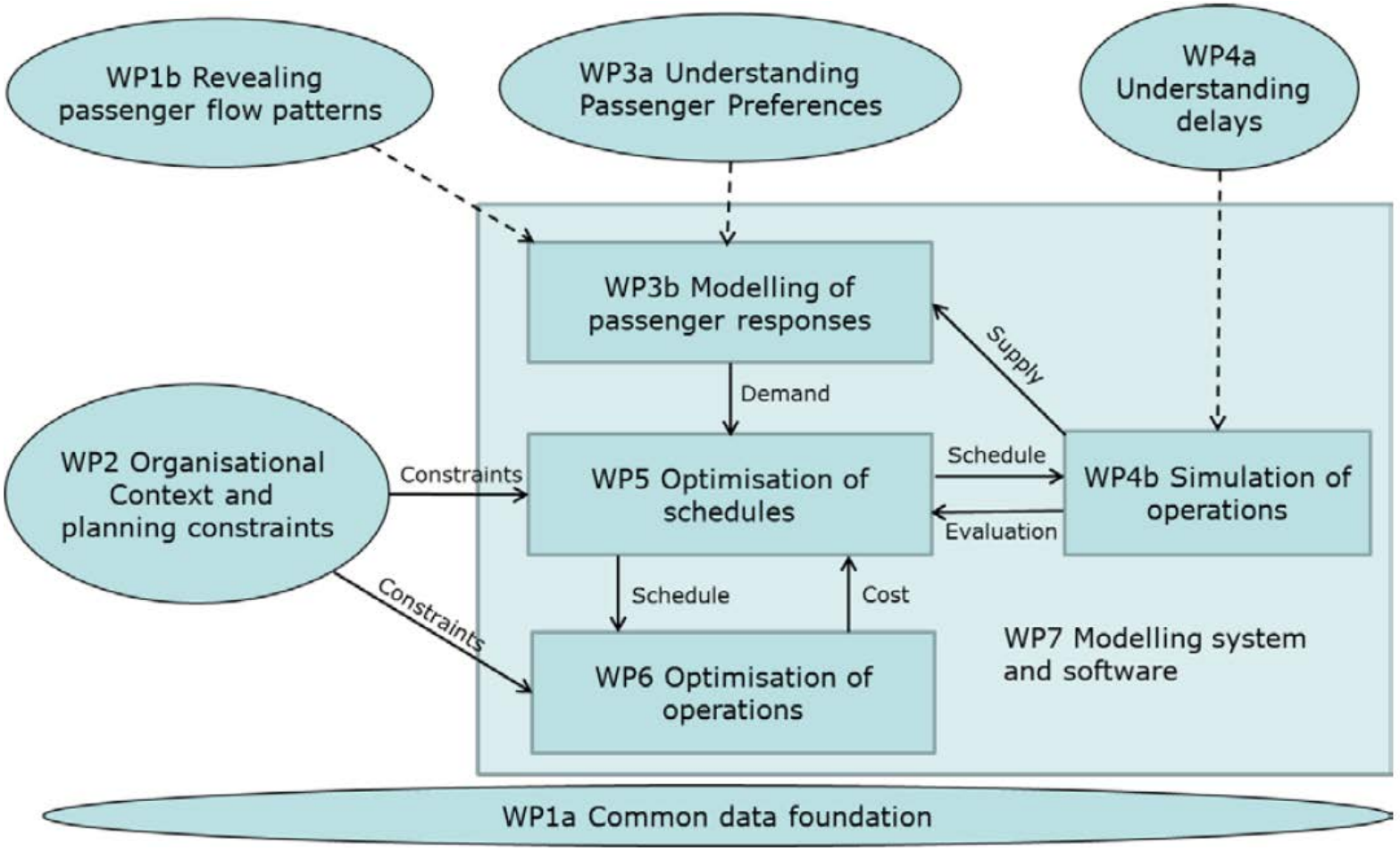
- 5% modal shift = 20% transit increase
- Low hanging fruit
  - Connections and transfers
  - Separate modes, operators
  - Is the network truly seamless?

Integration is Key

- Supply side of transit
- Stop patterns
- Frequency
- Timetable
- Transfers
- Vehicles



IPTOP Work Packages



Relevant Prior Work at DTU

- National Transport Model
- RobustRails
- Consulting

DTU Management Engineering
DSB S-Train

"Integrated Disruption Management"
&
"Robustness in Rail Operations"

(J. Larsen & D. Pisinger)

DTU Transport

"Optimization of Rail Operations with Regard to Passenger Benefits"

(O. Anker Nielsen & A. Landex)

DTU Informatics
Rail Net Denmark

"Formal (Model Based) Development and Verification of Railway Control Systems"

(A. Haxthausen)

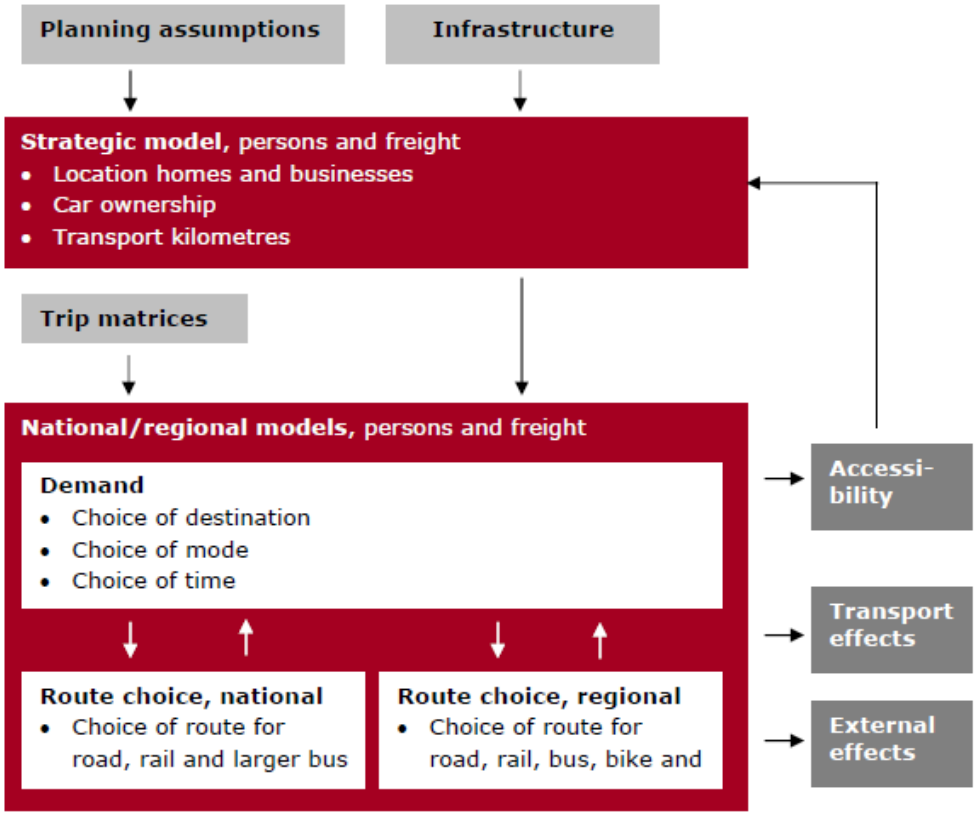
DTU Photonics

"Communication Technology Support for Railway Systems"

(L. Dittmann & J. Soler)

The National Transport Model "Landstrafikmodellen"

- Funded by the Danish Government at 60 million kroner ($10.5 mil.)
- Managed at DTU
- Project Life 2009 to 2020
- INTEGRATED
  - All modes
  - Whole nation
  - Freight and Passenger



Work Package 4

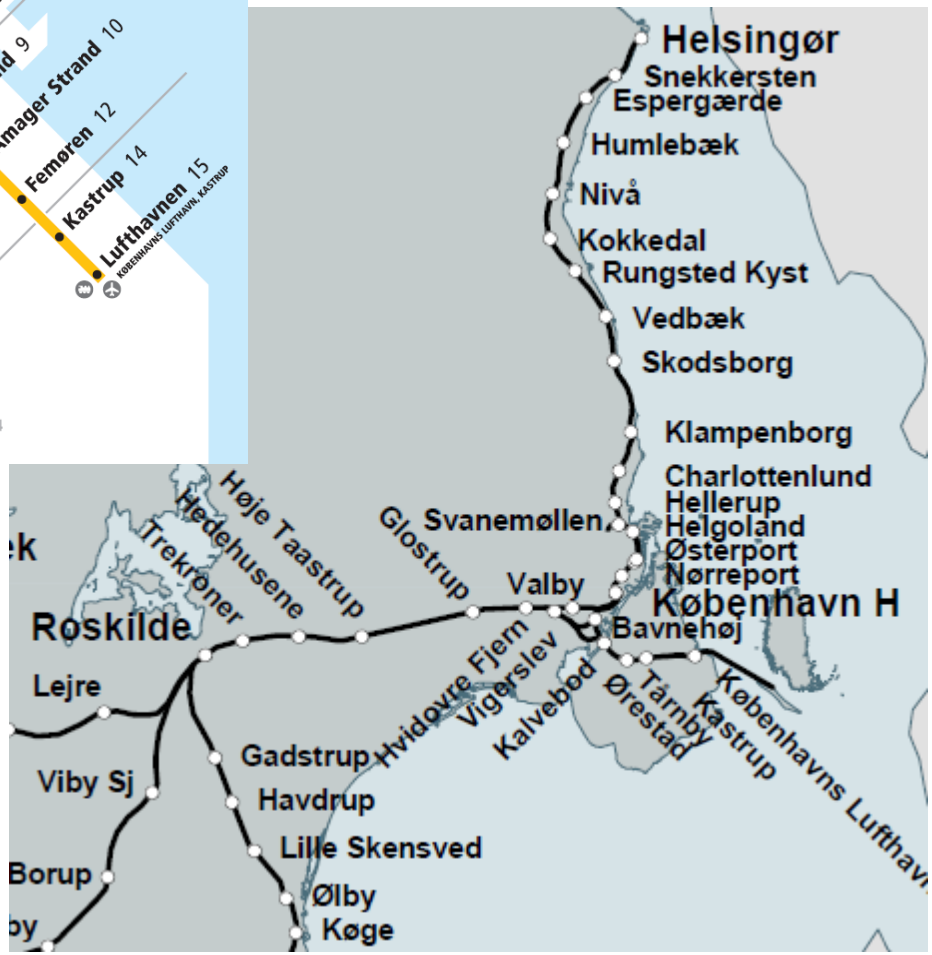
- Simulation of Operations
  - Vehicle network, not passenger flows
  - Whole network: bus, rail, & metro
- Five model groups
- Baseline 2014
- Evaluate timetable alternatives
- Return performance measures to
  - Timetable group (Work Packages 5)
  - Passenger demand group (Work Package 3)

Physical Model Groupings

- Metro
  - 125 second headway
  - Driverless
  - Unlikely to be of interest
- Long distance rail (“Fjernbane”)
  - Travelers both within capital region and to Jutland, Germany, and Sweden
  - Slower platform cycle time
  - Independent from suburban trains
  - Affected by freight trains

Fjernbane


Metro
Zone 2
Zone 1
Zone 1
Zone 3
Vanløse 9
Flintholm 8
Lindevang 7
Fasanvej 5
SOLBJERG
Frederiksberg 3
Forum 2
Nørreport
Kongens Nytorv 2
Christianshavn 3
Amagerbro 5
Lergravsparken 7
Øresund 9
Amager Strand 10
Femøren 12
Kastrup 14
Lufthavnen 15
KØBENHAVNS LUFTHAVN, KASTRUP
5 Islands Brygge
Zone 2
Zone 1
7 DR Byen
UNIVERSITETET
Zone 1
Zone 3
9 Sundby
11 Bella Center
12 Ørestad
14 Vestamager
Zone 3
Zone 4
M
M1
M2


Helsingør
Snekkersten
Espergærde
Humlebæk
Nivå
Kokkedal
Rungsted Kyst
Vedbæk
Skodsborg
Klampenborg
Charlottenlund
Hellerup
Helgoland
Østerport
Nørreport
København H
Svanemøllen
Valby
Bavnehøj
Glostrup
Høje Taastrup
Hedehusene
Trekroner
Roskilde
Lejre
Viby Sj
Borup
Gadstrup
Havdrup
Lille Skensved
Ølby
Køge
Hvidovre
Fjern
Vigerslev
Kalvebod
Ørestad
Tårnby
Kastrup
Københavns Lufthavn

Physical Model Groupings

- S tog
  - Independent network (1500 vdc)
  - No freight
  - Homogeneous rolling stock
  - Large existing data set
  - Potential for driverless future
- Lokalbane
  - Frequency <= 3 per hour
  - Light traffic
  - Minimal freight
  - Not expected to be significant

S tog

Lokalbanen

City Bus, Movia

- Independent lines
- Except
  - Some vehicle assignment dependencies
  - Bunching behavior in Copenhagen
- No single responsible
- Lines and line groups sub contracted
- High quality data (gps)
- 10% of vehicles with passenger counters

The Structure of the “Solution”

- A data table

Route	Stop Station	Arrival Time	Depart Time	Early Allowed
Train path	Name	Fjernbane Clock time		Yes, no time margin
		Stog time interval		

Arrival Variance	Depart Variance	Prob Cancel	Arrival Distribution	Depart Distribution
			Triangle Uniform etc.	

Proposed Correlation Matrices

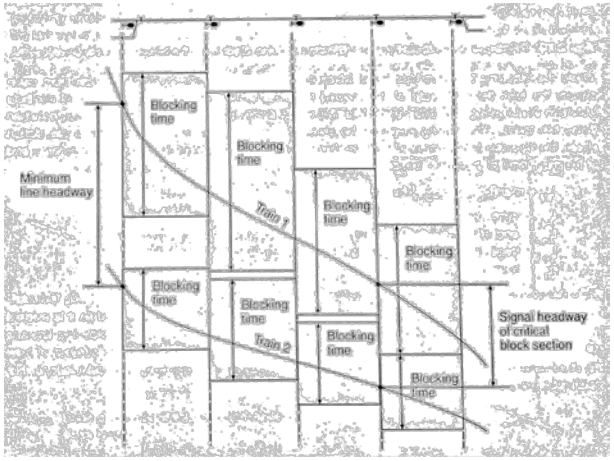
- S tog
  - 1000+ unique trains per day
  - Entirely periodic timetable
  - Route-direction-station x route-direction-station
  - e.g. [(As, Holte), (Es, Lyngby)]
  - Peak hour morning and evening
- Fjernbane
  - About 300 unique trains per day
  - Significant timetable aperiodicity
  - Train number-station x train number-station
  - e.g. [(0036, Helsingør), (0141, Nivå)]

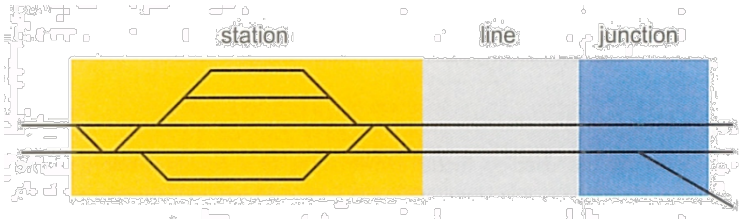
Ideas to Explore

- Guaranteed connections
  - WP4 operational feasibility
  - WP3 effect on demand and flow
- Early departure rules
- Buffer time allocation
  - Within train paths
  - Between train paths

The Tools

- Microscopic (actual tracks/signaling layout, detailed dynamics)
- Mesoscopic
- Macroscopic (line + stations, fixed running times)
- Synchronous or asynchronous?





Transportation (Railway) simulation PROCESS

SYNCHRONOUS:
all items updated in successive time steps

- Trains, Signals, Interlockings t=0
- Trains, Signals, Interlockings t=1
- Trains, Signals, Interlockings t=…
- Trains, Signals, Interlockings t=T

ASYNCHRONOUS:
trains added successively, timetabling

- Long distance, high priority trains
- Local, low priority trains
- Subordinate transportation means

Stochastic synchronous microsimulation
EXPECTED OUTCOMES

Bottlenecks

- Infrastructure
- Timetable

Delays

- Trace the causes
- Propagation

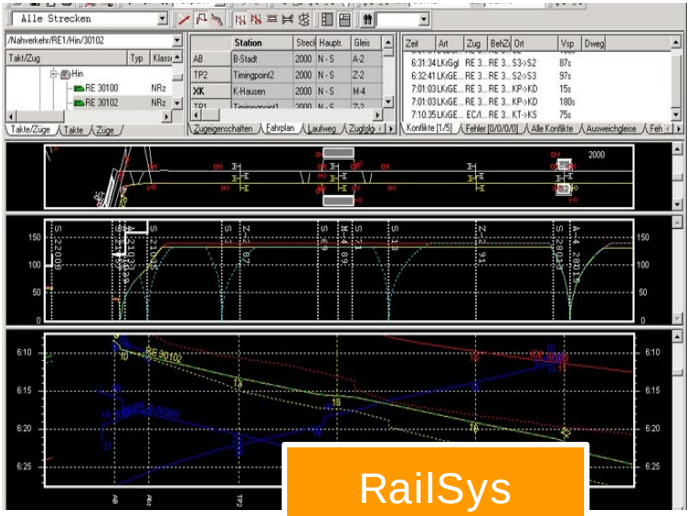
Quality of timetables

- Punctuality

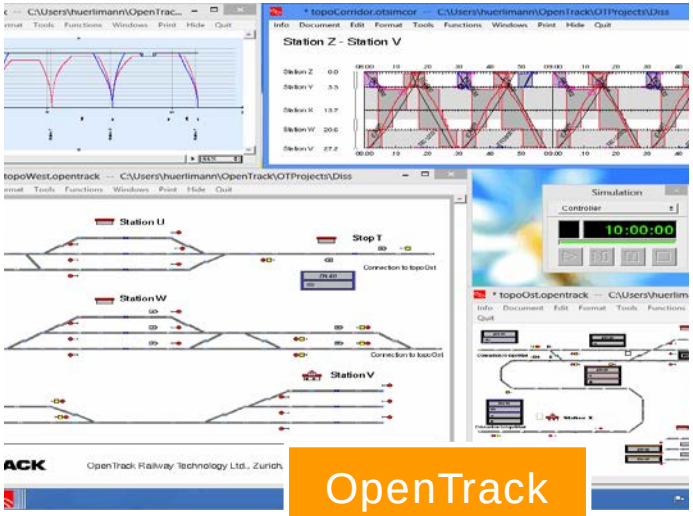
Operational strategies

- Supplement time allocation
- Synchronization with other modes

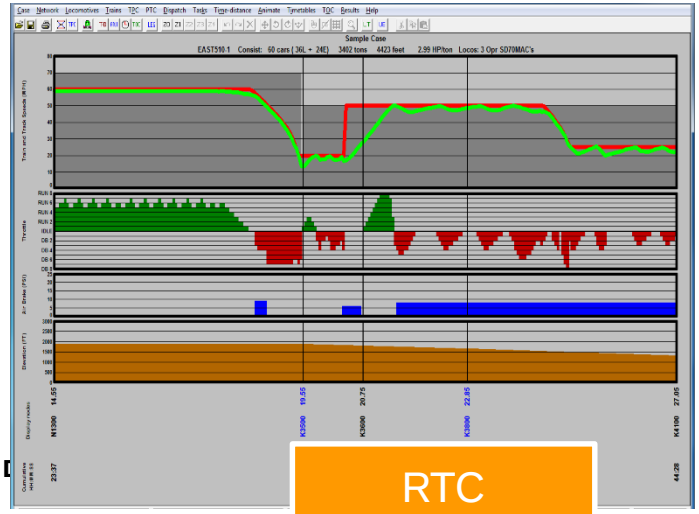
Stochastic synchronous microsimulation
MAIN TOOLS considered



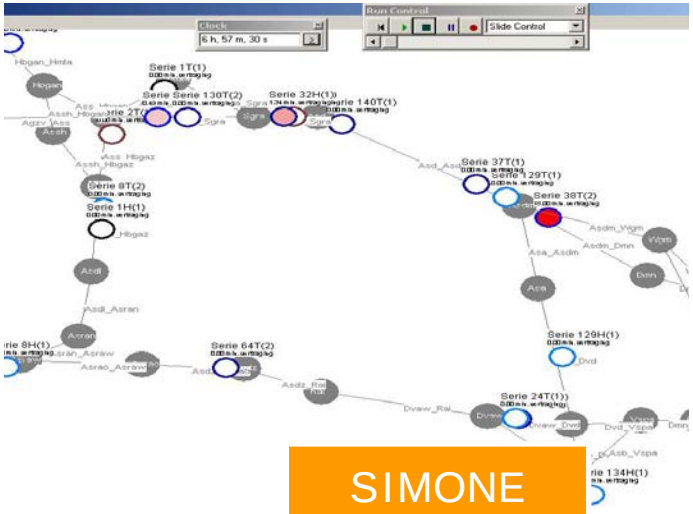
RailSys



OpenTrack



RTC



SIMONE

Pros and Cons

- Railsys
  - Long history in Denmark
  - Closed platform
  - Some obstacles
- Opentrack
  - Mature product
  - Open API
  - New to major partners (Banedanmark, DTU, etc.)

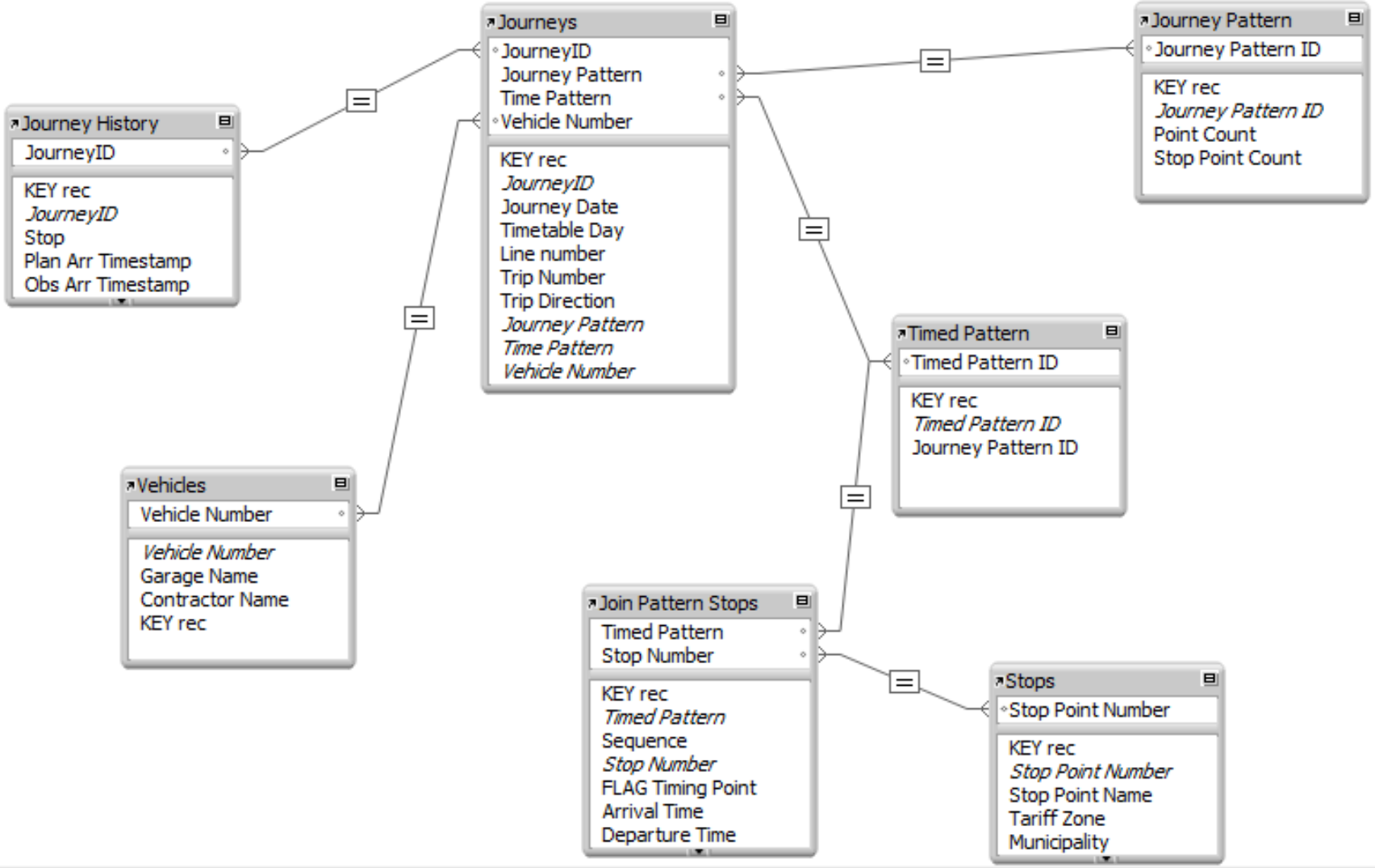
Pros and Cons

- Berkeley RTC
  - North American centered
  - Strong intelligent recourse dispatch
  - Our ”plan C”
- Simone
  - Netherlands Specific
  - Mesoscopic
    - Does not emulate signal blocks or terminal conflicts
    - Only 60 minute cycle
    - To explore: DVM & FRISO
  - Likely benchmarking candidate

The wheels are turning!

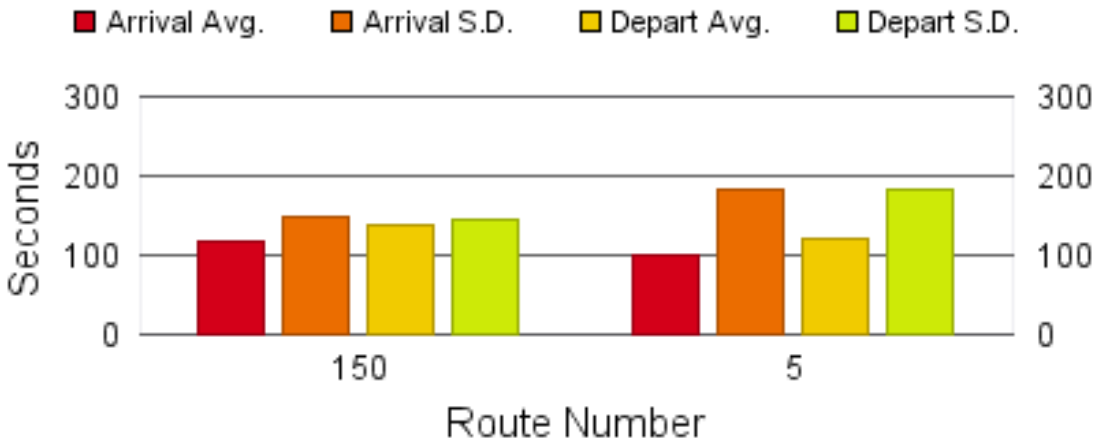
- First sample data from Movia
  - –27 November 2014
  - –32.829 data points
- Process for managing data
- Data structure
- Some results

Data Structure



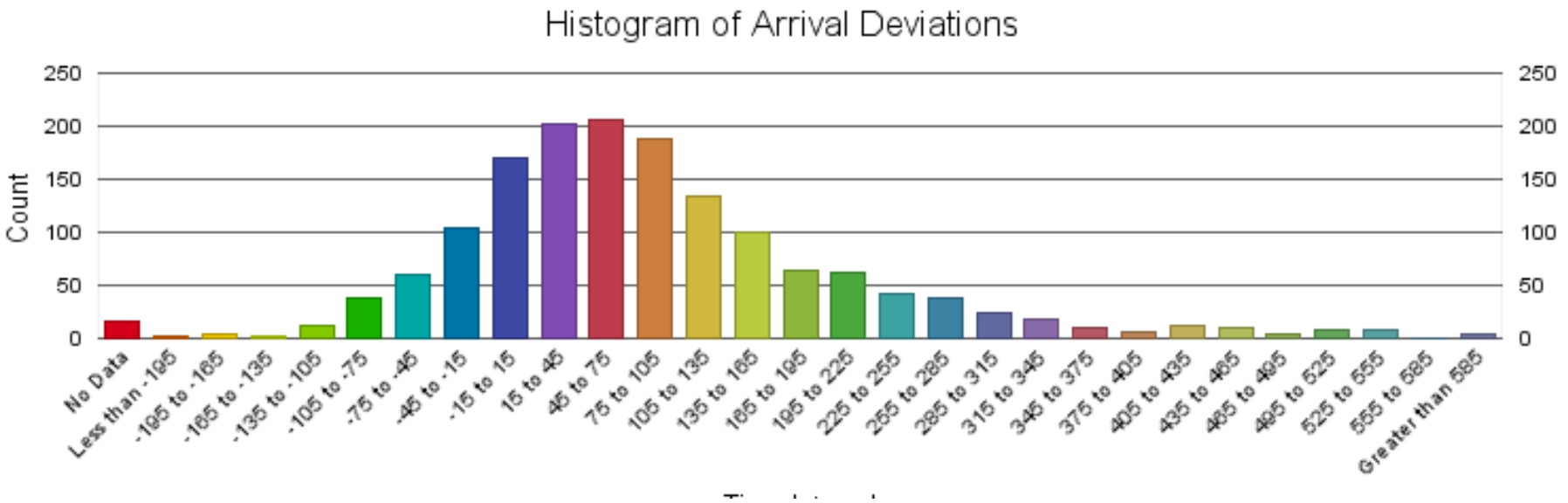
Results

		Arrival		Departure	
		Avg	S.D.	Avg	S.D.
Route	**150**	117.6	149.0	138.2	144.9
Route	**5**	100.1	183.2	121.6	182.0
All Data		104.3	175.9	125.5	174.2

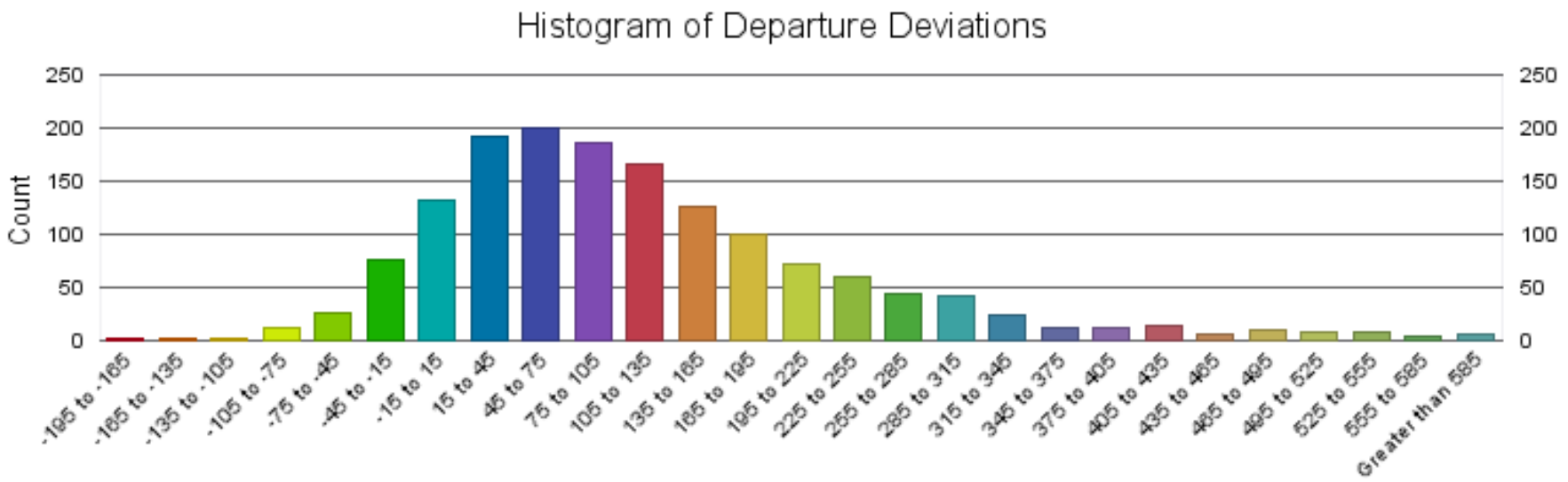


Selected Stops, Route 5

Arrival Distribution, Same Data



Departure Distribution, Same Data



Conclusion

- Choice of tools undecided
- Responsibilities of work packages defined
- Still negotiating data from rail operators

Tak for i dag!